Environmental Information System and its Application to the Kobe Area

Taiichi ITO

神戸における環境情報システムの緑地保全への活用

伊 藤 太 一

Abstract

Demands for geographical database are growing. However, most of the existing database contains only utility and land ownership information. Environmental information system has already developed in Kobe area because of the necessity to prevent disasters in the Rokko Mountain Ranges. Such information can be applied to other fields like open-space planning and recreational planning. Recently concerns for the amenity of the living environment is rapidly increasing. However, the mere existence of the database is not enough to improve it; they must be debugged, used and renewed constantly.

In this study, the application of the database of Kobe area to environmental planning process is discussed, and some recommendations are suggested. The unit of the database is 25 m by 25 m square, and the whole area of the city comprises about 1 million such squares. Each cell consists of integer data of 2 to 3 digit codes A part of these data was stored in floppy disks and examined with softwares of image processing for microcomputers.

After obtaining the general scope of the data, a large computer was utilized to process the whole area. The over-lay method was applied to some environmental information such as inclination, landuse, and geological features. The results were printed on papers using a color plotter. They were very accurate and reliable. This method enables us to produce print-out of a large area with high resolution in a short period, but the burden to the computer is high. In order to reduce the cost and complexity of data handling, a simple line-by-line data format is recommended. At the same time, using LANDSAT TM data is preferred to current man-made landuse map.

要 旨

近年，地域情報の処理の合理化，迅速化を進めるために，地理情報データベースの整備が行政の側から望まれている。しかしながら，実際に作成しすでに運用しているところはまだ限られて

いる。さらに，それらの多くは道路網や水道，ガスなどの施設や課税のための土地区画などのデータに限定されている。

これに対して，神戸市域には土地利用，地形，法規制などを中心とする環境情報のデータベースが存在する。六甲山系の防災上の必要性がそれらのデータベースの主目的であると考えられるが，それればかりではなく，緑地などのアメニティにかかわる市民の住環境の整備にもおおいに貢献できる。また，生活の質に対する関心が高まっている今日，他地域の環境情報のデータベース化に対して大きな影響力を与えるといえる。しかしながら，様々な分野でデータベースが作成されているが，活用されないものも少なくない。この理由としてはそのデータ自体の内容もさることながら，必要な情報を取り出す手間がかかるとか，どのように応用できるのか具体的な使い方がわからないというような原因が考えられる。とりわけ，環境情報は住民参加の見地からも，公開され活用されることが望ましいことであるから，使いやすさは重要である。

今回，用いたデータベースは，25m四方の正方形が最小のユニットで，約百万個で市域をカバーしている数値化されたグリッドからなる。データ数が多いため全域の処理を行なうのには容量などの問題があらかじめ予想されたので，一部分のデータを切り出し，マイクロコンピュータ用の画像処理ソフトウェアを用いる方法についても検討した。

本研究においては，マイクロコンピュータによる狭い範囲での緑地保全のためのデータ間演算の試行錯誤の結果を大型計算機センターで全体に対して当てはめて結果をカラープロッタに出力するという方法を取った。このようにデータ間の重ね合わせを行なうことによって様々な目的である要因を抽出したり，ランキングする手法はよく活用されているが，画像として大量のデータを処理することによってより広範囲をより高精度で捉えることができるようになった。これによって地域の計画や環境影響評価などの多方面に活用されることが容易になった。その場合，25m単位の情報が正確であることおよび定期的にデータが修正，更新されていくことが必要条件である。また，土地利用のデータとしてランドサットＴＭデータを統合化して用いることが有効である。

1. Introduction

Because the concern of disasters occurring in the Rokko Mountain Range has been very strong, there are some environmental databases in the Kobe area[1] They consists of both natural factors such as topography and vegetation, and man-made factors like roads and regulated areas.

An information system like this has become indispensable in these days for application for various planning. However, there are many unused databases. This is because they are not easy to handle the data. Visible output is also important to encourage the use.

In this paper, the applicability of the system is examined from the view point of the conservation of existing vegetated areas and recreational possibilities. Some recommendations for the improvement aiming at user friendliness are also suggested.

2. Characteristics of Kobe City (Fig. 1)

Kobe is located at the western part of the Kansai Region of Japan, and has a population of 1.42 million, and the area is about 546 km². The topography is characterized

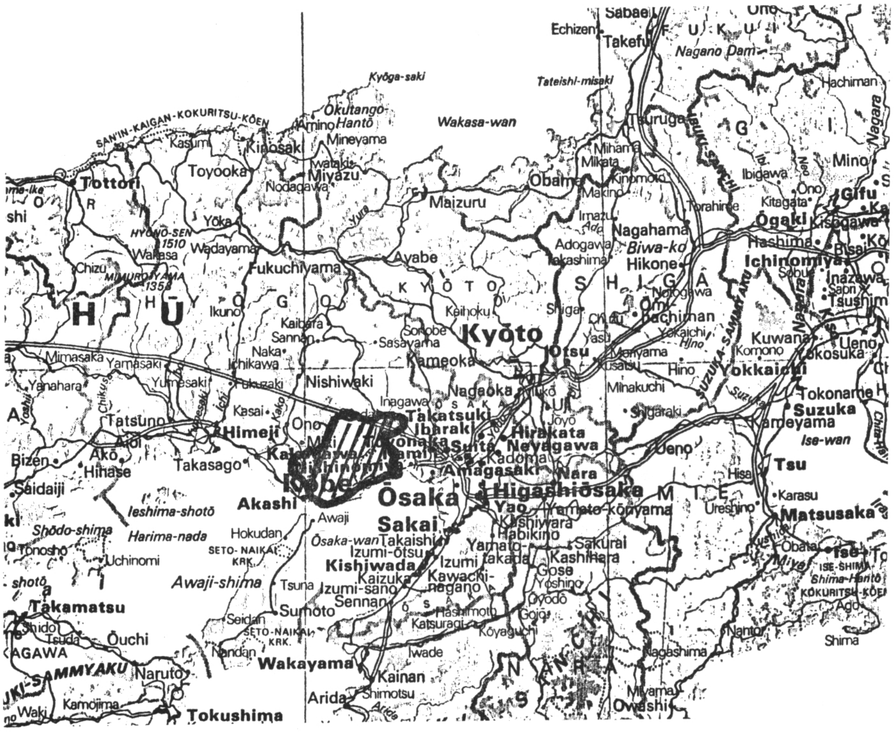

Fig. 1. Location of the Kobe City in Kansai Region.

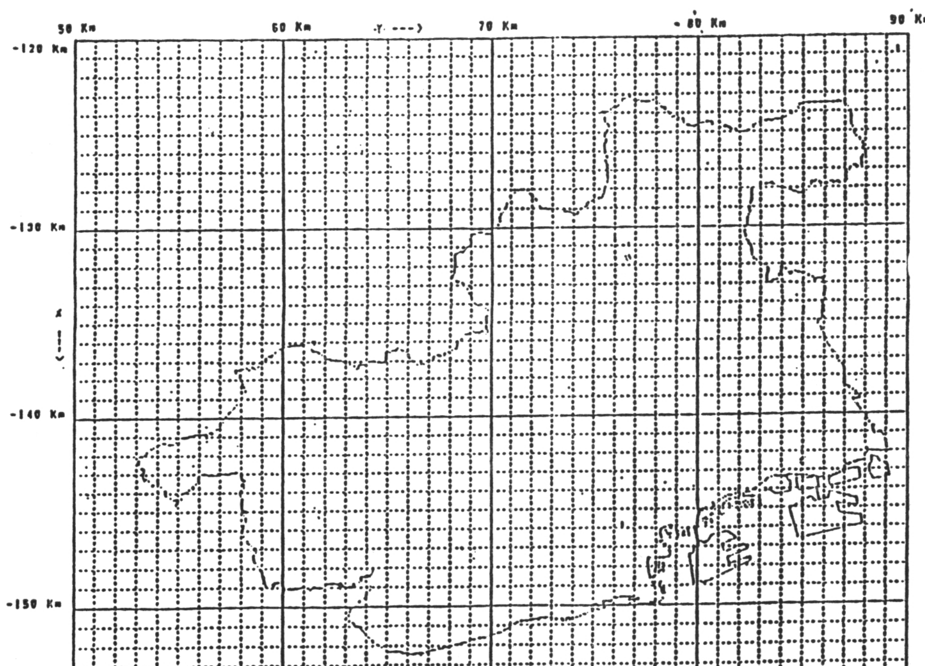

Fig. 2. Classified Area and the Coordinate System

by the Seto Inland Sea and Rokko Mountain Ranges. The Ranges, which runs east to west, divides the city into densely populated southern area and agricultural northern area. The Rokko Mountains give the city various scenic resources and recreational opportunities. However, at the same time, the Range also caused several landslides and floods. Therefore, planning strategy to enhance the positive opportunities of the Ranges while decreasing the negative aspects is necessary.

3. The Outline of the Environmental Information System in Kobe (Fig.2)

The database system consists of grid-divided square data units. Though some of the information is available only in vector forms, they were transferred to grid-type data. This is very important. Though vector-type data has advantages in processing linear-type information such as roads and rivers, grid-type data is preferable for making composite maps since the image processing methods have become applicable for the grid data type.

The city is divided into almost 1 million 25m by 25m squares based on the basic coordinate system used by Geographical Survey Institute of Japan. The origin located at the northwest point with the latitude of 36°00', and the longitude of 134°20'. The information on the individual square was obtained from 1/10,000 scale base map using a digitizer, which is a tool to input a set of coordinate values.

Each cell represents information in $625m^2$. It is often the case that various attributes such as a river, and a road along the river, may be found even in one cell. In such a case the most dominant factor was chosen as the information of the cell.

In this study, the following data information is processed.

1. Landuse and vegetation.
2. Geological feature.
3. Altitude.
4. Inclination and aspect calculated from the altitude data.
5. Regulated area by law.

Each cell has this various information. All data use 2 digit code numbers except for the inclination data which is 3 digit. That is, because there are about 1 million data cells within the city boundary, the system contains more than 6 million data. This huge volume of the database system has both advantages and disadvantages. The first is the size of each cell; 25m by 25m square is very close to the area surveyed by LANDSAT Thematic Mapper (TM). Combining the TM data with this information system, which is developing now, will enhance the quality of the environmental information and can be a strong tool for planners. The second is the minuteness of the information in comparison with other available geographical information system. For example, the National Geographical Institute has been supplying national geographical digital information. This covers the whole area of Japan with 370,000 cells with the grid interval of 1km. In densely populated Japan, complicated mosaic-like landuse is common. Therefore a cell of $1km^2$ is too large to express any specific information. Especially on a city-level planning process, hundreds of such large information cells are enough to cover the city of Kobe, and this coarse information is of no use.

The disadvantage is common to any huge databases ; the difficulty of processing the data[2]. While the capacity of computer is rapidly expanding, the limit of the memory capacity can be easily reached. Though we usually need only a part of such data, we have to extract and read all the data under current formatting system.

Another point about which a user of such database has to be very careful is the quality. The original information is based on 1/2,500 or 1/10,000 scale maps. The distance of 25m is only 2.5mm on the 1/10,000 scale map. In addition, the data is picked up one by one by a person. The use of a digitizer might have reduced the human errors, but each decision to select a code number is made by a person. Some apparent errors in code selection have already been found. Therefore, periodical data renewal is strongly recommended.

4. Inclination and the Aspect

The degrees of inclination and aspects were obtained from the altitude data. As mentioned above, some wrong values in the data were already found, but those were ignorable. The inclination is given using a percent unit : 100% means 45°. The aspect was given with degrees ; the minimum is 0° and applied to the south facing slopes, and 180° means a north facing slopes.

5. Preview Using a Microcomputer

In order to reduce the problems common to processing a large data set, the use of a microcomputer was tried out. There are some image processing softwares available in the market. Most of them use floppy disks as a source of the data. The data format for the LANDSAT images developed by Remote Sensing Information Center of Japan is used because most of the softwares aim at the processing of the LANDSAT data supplied by the Center. One scene consists of 512 by 400 pixels, that covers an area of 12.8km by 10km if the real length of one pixel is 25m. Four types of data can be stored in a 1 mega byte floppy disk.

Each pixel occupies one byte data space This means each data should be stored with an integer value ranging from 0 to 255. Though most of the information is stored as numbers ranging from 0 to 100, the altitudes and the relevant data such as inclination are out of the range because Kobe occupies the coastal area (0 m) to the top of the Rokko Mountains (932m). In case of such out-of-range data the maximum number was divided into 256 classes, and then stored in the floppy disk. By allocating one color to each class, the characteristics of each extracted area became clear. Then two scenes were put together and so-called over-lay method was applied. Unfortunately the software was not equipped with logical calculation function such that A and B is equals to C, A or B is equals to D. However, this function can be substituted by applying 4 rules of arithmetics. If factor A has a value of 1 and factor B has a value of 10, A and B can be expressed as

11, A or B as 9. Because the computer requires longer time to do logical calculation than 4 basic arithmetics, this alternative approach reduces the computation time.

One byte data stored in a floppy disk requires minimum storage space and the microcomputer can handle them if the area is limited to 12.8km by 10km. The area we usually deal with is less than this size. For this reason, the use of the microcomputer has advantages over the main-frame computer unless the whole area must be viewed for planning.

6. Output Using a Large Computer System

After examining sample areas with a microcomputer, the same classifying method was applied to the whole area using a large computer system at the Data Processing Center of Kyoto University. The system has several ways for producing images.

The image processing system is equipped with a high resolution display unit(1280 by 1028 pixels). This enables interactive presentation of the environmental information. However, the database has many more pixels(1,600 by 1,400), and presenting the whole area in one scene was deemed necessary. In addition, high quality hard copies were indispensable in the planning process. For these reasons, the color plotter system produced by APPLICON was chosen.[3),4),5)] This plotter has 4200 by 2752 addressable points, and each cell has a length of 0.2mm. In this study, a square of 0.4mm by 0.4mm consisting of 4 dots is allocated to each environmental data.

The original data format is complex ; the data is blocked, and each consists of 16 data, and randomly recorded. The first step was to reorganize them into a line-by-line sequence. Secondly, each data was classified into a designated category. Then a color was given to each data according to the category. The basic 8 colors can be selected by controlling magenta, yellow and cyan inks. The results are once stored in the magnetic disk of the main system then copied onto magnetic tapes. The color plotter reads the data in the tape and draws maps on the paper with the size of 81 cm by 51 cm.

7. The Classified Maps

The vegetation, altitude, inclination, aspect, regulated area by law, and geological data were used to obtain the following print-out. the altitude data covers some of the area beyond the city boundary, others are limited within the city boundary.

7.1. The Aspects of Slopes (Fig. 3)

The altitude of the each cell was read from 1/2,500 map by 1 m resolution. This is rather high precision, but it should be noted that the height is based on the ground level. The ground is usually covered with trees or man-made structures exceeding the resolution level. When this data is applied to the visibility check, the height of these components should be added.

The data of slope inclinations and aspects were generated by producing a

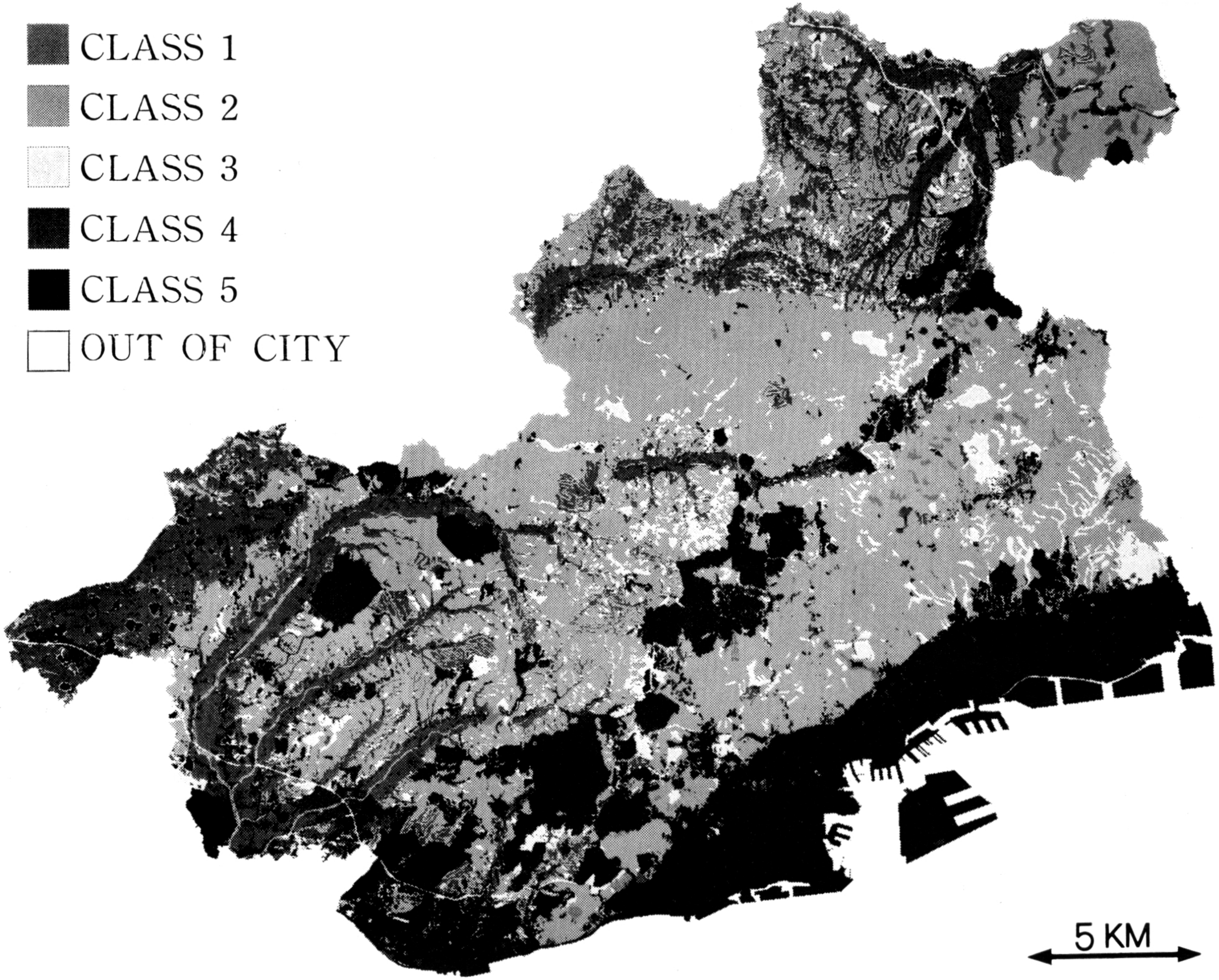

Fig.4. The Landuse and Vegetation

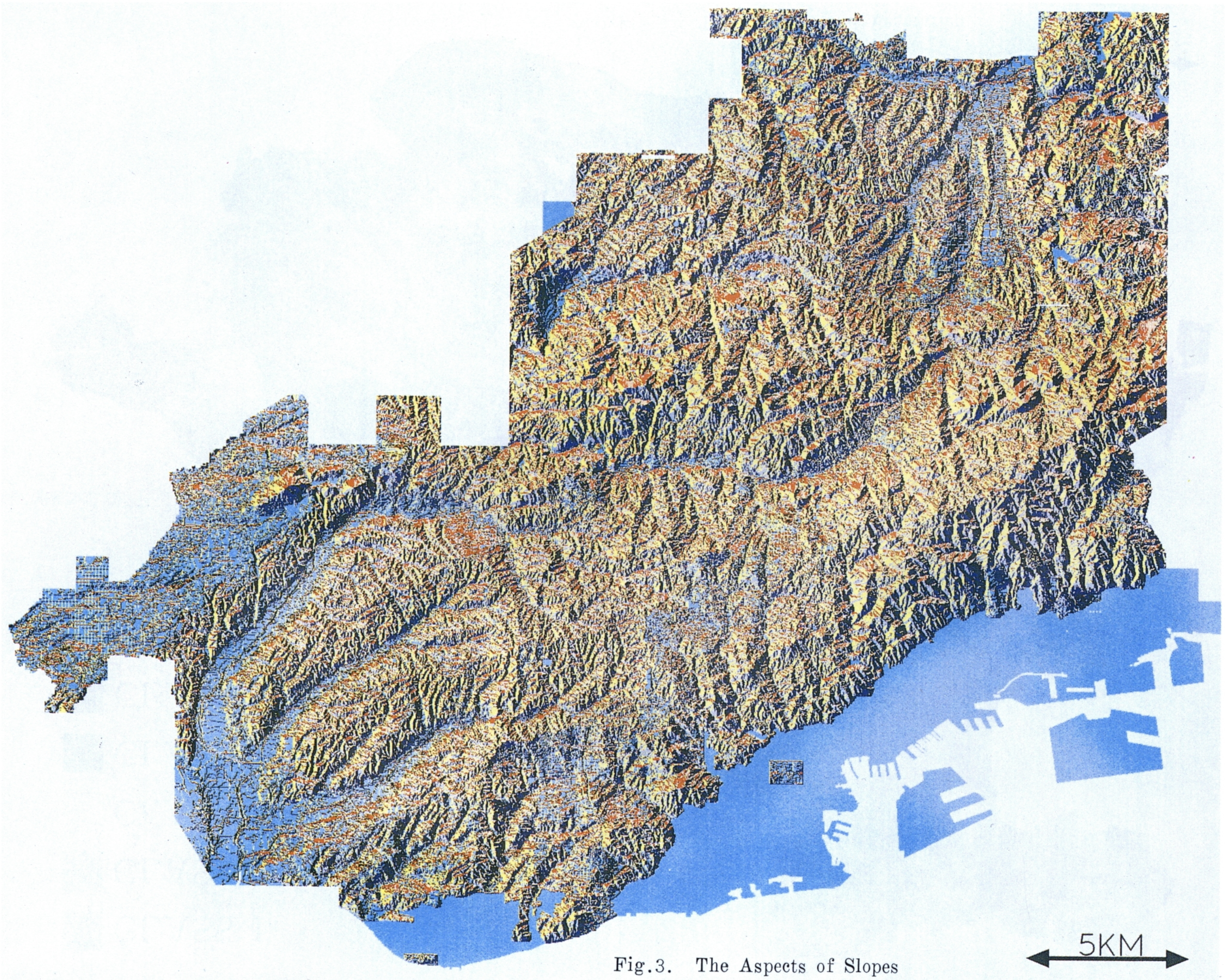

Fig.3. The Aspects of Slopes

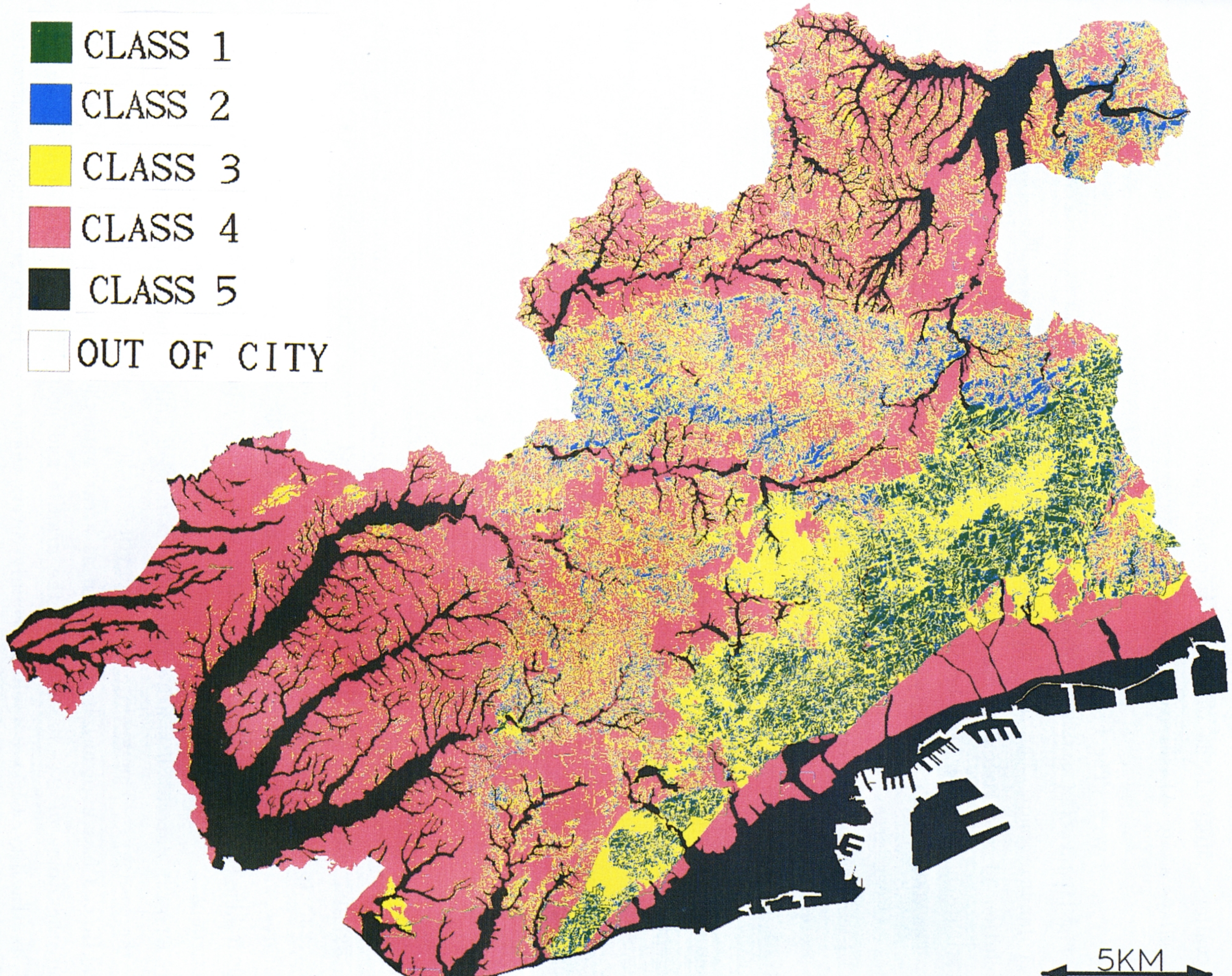

Fig.5. The Safety Factor

hypothetical plane using 4 altitude data. A map of aspects were produced to obtain general ideas of the study area. This relief map assumes that light is coming from the northwest corner. the map clarifies the directions of tectonic lines as well as ridges and valleys. Most of the population is concentrated in the blue-colored coastal zones and the valleys along Akashi River.

7.2. The Landuse and Vegetation (Fig. 4)

The landuse and vegetation database consists of 40 categories based on the information from landuse map. The data was read from 1/25,000 scale map. For this reason, the resolution of each cell does not seem to be very reliable. (The use of TM data as the substitute information will be discussed later.)

The area beyond the city limit was given the color white which is common to other maps. Other areas were divided into 5 categories. Class 1 (originally green) contains broad-leaf natural forests. This type is regarded as important vegetation and should be preserved. Class 2 (originally cyan) has pioneer-type vegetation such as red-pine forests and pampas grasses. In the future, this type of vegetation will move to the next stage of succession, which is Class 1. Class 3 (originally yellow) is made of man-made forests like cypress, and grasses common to suburban areas. Class 4 (originally magenta) is mainly agricultural landuse. Finally Class 5 (black) is urbanized areas. The concentration of agricultural landuse is in the western part of the city along the Akashi River and the northern part along Nagao River. Class 5 includes bare lands and inland water surfaces. There are some conspicuous worm-eaten-timber-like patterns scattered in the forested areas. They are golf courses. Linearly allocated large scale developments for housing in the northern part of the Rokko is obvious.

7.3. The Safety against Disasters (Fig. 5)

The combination of slopes and geological features was used to examine the vulnerability against disasters. The inclination was divided into 5 ranks: less than 15°, 15° to 23°, 23° to 30°, 30° to 45°, and more than 45°. Depending on the fragility, geological features was classified into 3 ranks. The most fragile one is granite which is common to the Rokko Mountains. Therefore an area with steep slope and granite is ranked as highly hazardous.

Class 1 (green) has more than 45° inclination and is therefore dangerous regardless of the geology. The granite and propylite of 30° to 45° were included because of its fragility. Class 2 (cyan) is designated as areas with the inclination between 30° and 45°. But the range of 23° to 30° with the granite and propylite was included again because of its fragility. Class 3 (yellow) mainly covers the area of 15° to 30°. Class 4 (magenta) is allocated to gentle slopes of less than 15° except for the area with the above mentioned 2 features. Class 5 (black) is flat alluvial plain with little possibility to undergo a disaster.

The map clearly point out that the Rokko Mountain Ranges, especially the southern side adjacent to densely populated area, has steep slopes made of granite and is

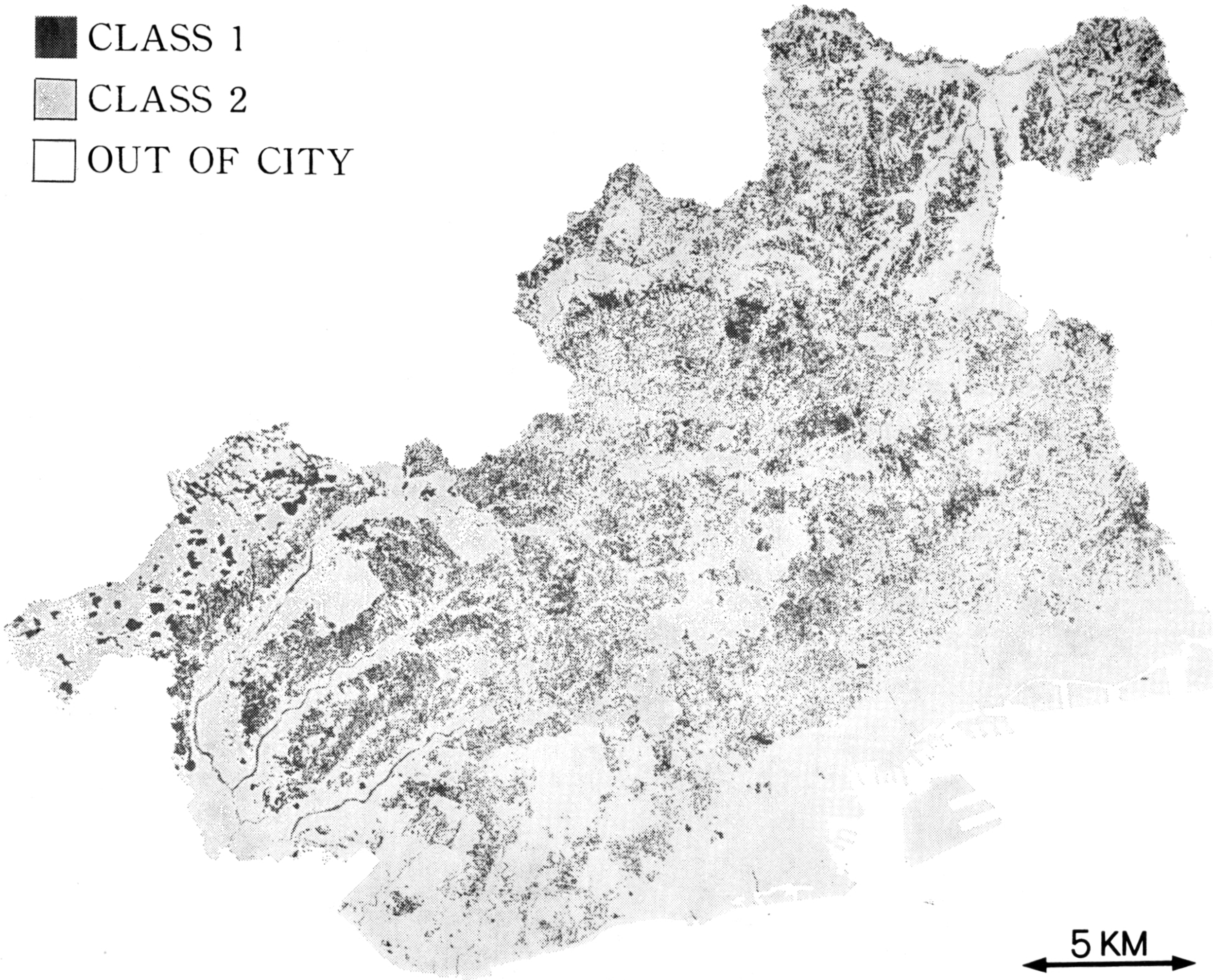

Fig. 6.   The Recreational Values

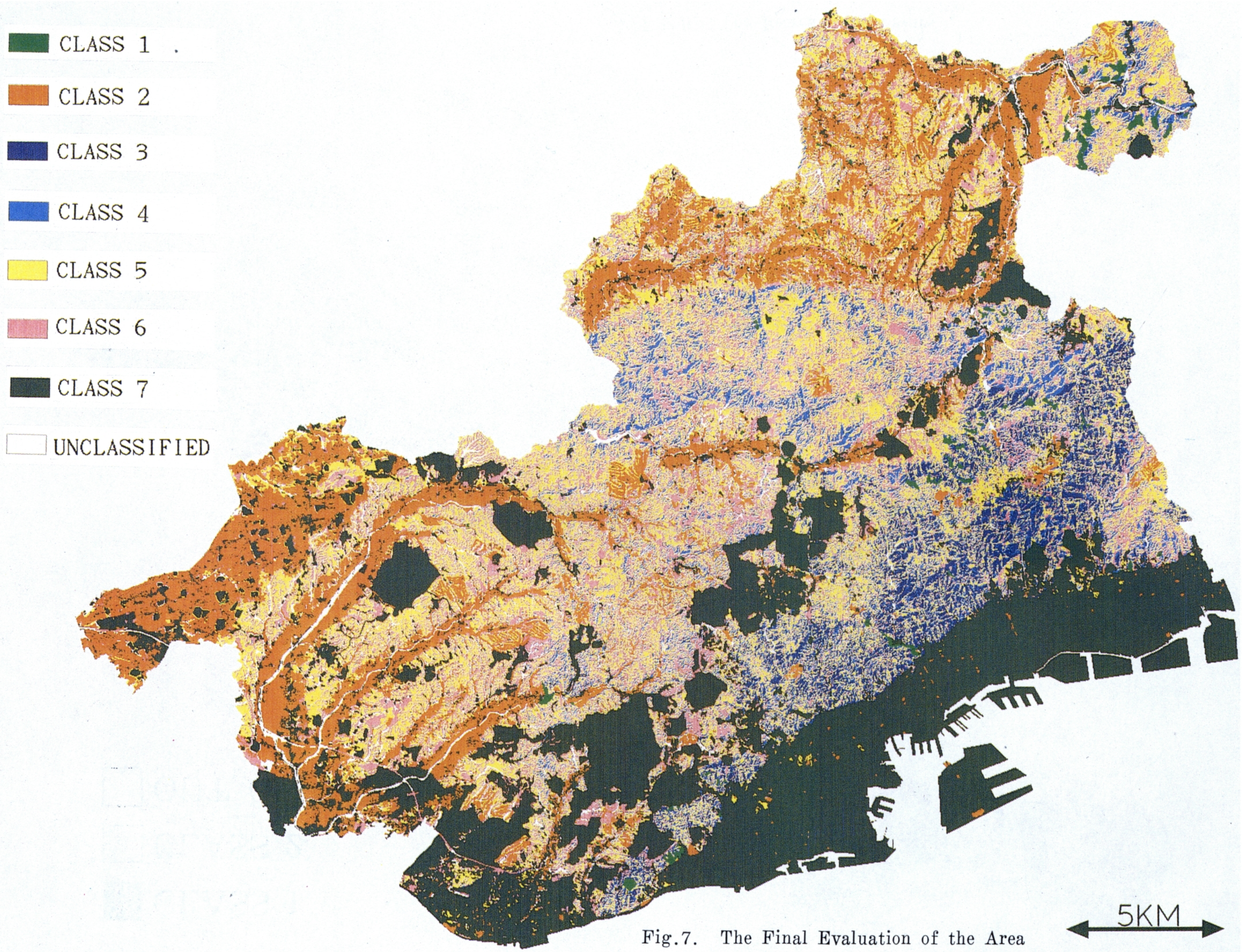

Fig.7. The Final Evaluation of the Area

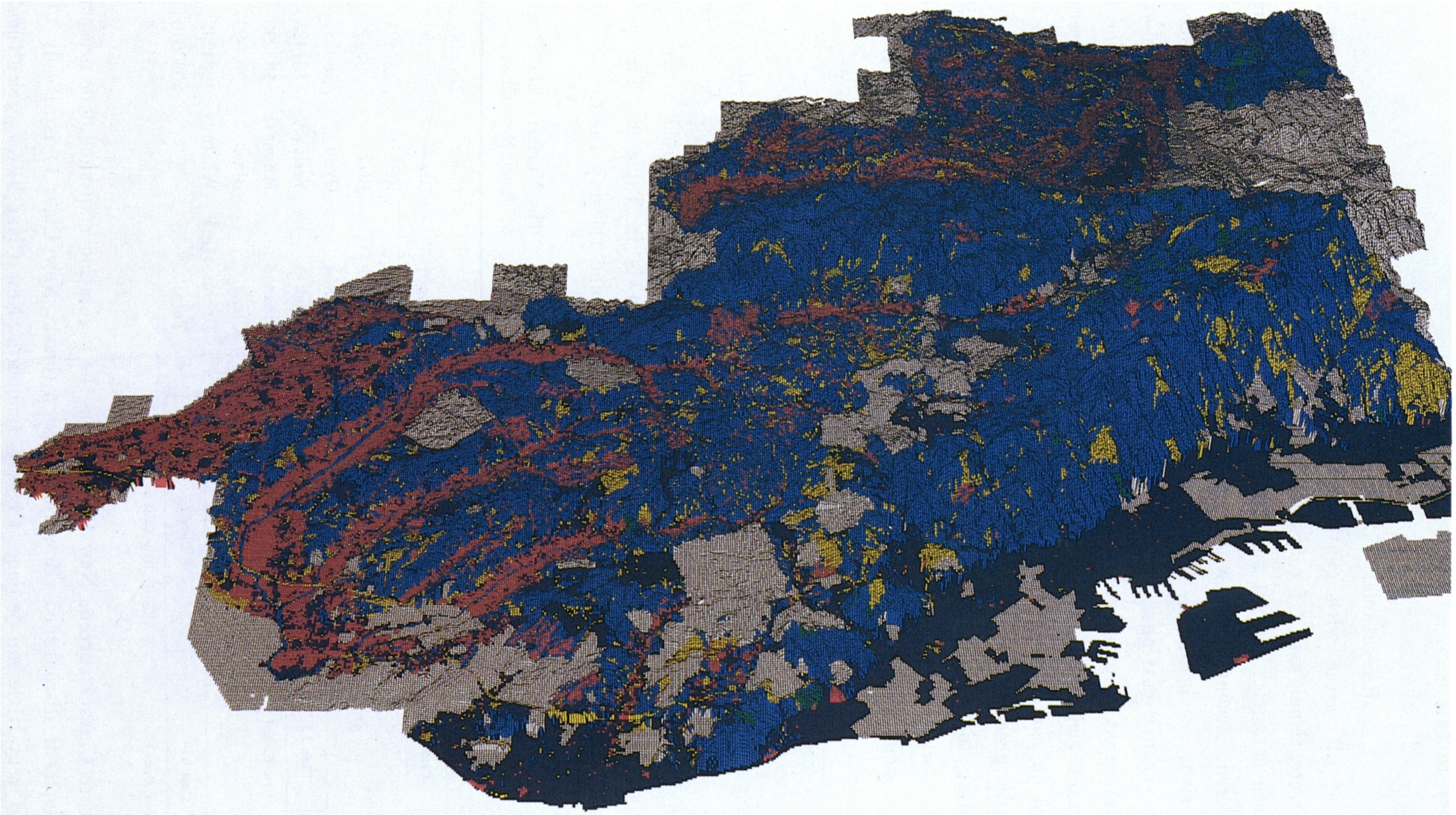

Fig. 8. The Perspective Drawing with Vegetation

dangerous. The tectonic lines were not clear in the aspects map, but identifying these lines is easy in this map.

7.4. Recreational Values (Fig. 6)

First of all, areas with gentle slopes of less than 15° were regarded as suitable sites for recreational use. Of course there are some activities which prefer steep slopes. Because such activities are not suitable to include to this type of classification, they were not considered. Among areas with gentle slopes, sunny forested areas with access to a lake or a river are preferred. However, recreational activities damage the forests by soil compaction, branch cuttings, and possible fires, and natural forests should be exempted because they must be preserved than used and damaged. For this reason, red pine forests, pampas grass fields and water surfaces were selected as suitable areas to recreational use. Based on these standards, areas with recreational-use capacities were chosen as class 1 (originally green). Class 2 (originally yellow) is other areas in the city.

According to the map, the recreational potentials are scattering over the region, but the density seems to be higher at Tanjo-Taishaku hills. The western part of the city with many irrigational ponds were also ranked as areas with high recreational potential.

7.5. The Evaluation of Total Landuse Based on the Data of Three Analysis Maps (Fig. 7)

The results of the above mentioned three maps were stored as new databases, and they were compared in a program to determine suitable landuses based on the environmental requirements and on the view point of conservation of vegetated areas. The new categories are explained in Table 1, and the distribution is in Table 2. The percentage of unclassified area in the Table 2 includes the area beyond the city limit.

Table 1. The Evaluating Method at Final Classification

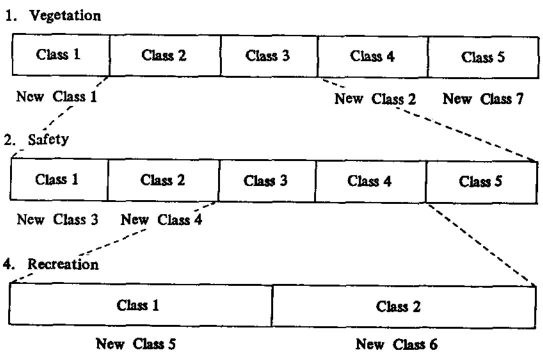

Table.2. The Numbers and Percentages of Each New Class.

	Color	Number	(%)
Class 1	Green	5397	0.26
Class 2	Red	134494	6.47
Class 3	Blue	37925	1.82
Class 4	Cyan	60337	2.90
Class 5	Yellow	161423	7.76
Class 6	Magenta	183393	8.82
Class 7	Black	262999	12.64
Unclassified	White	1234042	59.33
Total		2080010	100.00

The rare Class 1 (green, New Class 1) on the vegetation map should be preserved and any development discouraged. However, Class 5 (black, New Class 7) is already urbanized areas, and very little can be done. Class 4 (magenta, New Class 2) is agricultural lands, and should be kept as they are. Other areas, Class 2 (cyan) and 3 (yellow), are subject to various changes in the future. It is in these areas that careful far-sighted planning is required.

In the safety map, dangerous areas were classified as 1 (green, New Class 3) and 2 (cyan, New Class 4). These areas should be carefully observed and preventive measures required. In such areas, any other landuse will not be allowed. Flat areas (Class 5) are already urbanized or agricultural lands, and were exempted from the new classification.

The areas not covered yet are Class 3 and 4 in the safety map in Class 2 and 3 of vegetation map. From these areas, suitable areas for recreational use were chosen (New Class 5). Finally left-out areas can be called neutral or open-use areas (New Class 6) because any specific conservation strategy is not suggested.

The map thus obtained has classified the city area into 7 ranks. The first class (green) is scarce natural forests. The second (red) is agricultural areas. Class 3 (blue) and 4 (cyan) are both hazardous areas. Class 5 (yellow) is suitable for recreational use. The Class 6 (magenta) is open-use areas. The last Class 7 (black) is already built-up areas, and little vegetation is left. Unclassified areas (white) lack vegetation.

This classification of seven categories is mainly based on vegetation and topography. There can be many other ways of classifying the same area. For instance, by using soil database suitability to agricultural use will be shown.

The computer enables us to obtain maps which cannot be drawn by man power. However, processing millions of logical calculation is a burden even to the large computer, so skills of the programmer is to be encouraged in order to process the data efficiently.

8. Perspective Drawing with Vegetation (Fig.8)

The viewer's position was set above the Seto Inland Sea in this perspective drawing. There are three advantages in presenting the landscape with a perspective drawing. First, every one can easily identify the place, which is a prerequisite when public participation is wanted. Second, as a tool of simulation, the perspective drawing can be used to predict the modified landscape after changing landuse or topography. For example, Port Island and Rokko Island were reclaimed by soils from hills which disappeared, therefore the landscape changed dramatically in recent years. Finally, the perspective drawing consisting of polygons can show various environmental factors with the topography always presented.

9. Conclusion and Recommendations

The color-plotter output is revealing and can be a very powerful tool in the planning process. However, the process is not easy and has several problems. First, the file access numbers can easily reach the allowed limit. Two, the memory of working area can easily be overflowed by setting up a huge dimension size which is common to a environmental database. Third, the cost is estimated by the computing time and the used file storage space; processing of millions of data requires much time and money. Finally, the access to such an expensive plotter for the large data processing system is limited. For these reasons the following is recommended.

1. The data format must be considered carefully. Simple line-by-line format saves a lot of file space while dramatically reducing the dimension size. If possible, each pixel data should be stored in one byte integer code.

2. If a part of the data like an area of $100km^2$ is required, use of the micro-computer is strongly recommended. The price is moderate and the operation is easy. In order to use it. the data must be supplied with floppy disks.

3. Periodical renewal and debugging is indispensable to keep the information usable. Since debugging is a troublesome process, a manual for the purpose should be carefully prepared. At the same time, the old data should be kept as historical records.

4. The addition of the satellite surveyed data like LANDSAT TM data is recommended as an alternative to man-made landuse data. It is difficult to obtain cloud-free full-scene data (185 km by 175 km), but scores of cloud-free data can be obtained each year if the area is limited to the municipal level. For instance, Kobe can be covered with a 40 km by 30 km scene. The cost of producing a satellite data is much cheaper than man-made ones, and they are free of human errors.

In addition to these computer related suggestions, it should be noted that the evaluation cannot be made by a computer ; using the same database, different results can be made. In order to objectify the results, the process of evaluation should be thoroughly discussed in a committee consisting of specialists and professionals of each field.

Acknowledgments

Dr. Sumiji Kobashi was generous enough to let me use and modify his program to calculate slopes and aspects. The whole process was done at the Data Processing Center of Kyoto University. The maintenance of the color plotter is very complicated. The author wishes to express heartful thanks to those working in the Center.

References

1) KOBASHI, Sumiji : The Database for Mountain Disasters Control and Environmental Conservation at Rokko Ranges (Japanese), Bulletin of the Data Processing Center. Kyoto University. **20** (3). 1987

2) ITO, Taiichi : The Landuse Changes in the Kansai Region Observed by LANDSAT Satellite. Bulletin of the the Kyoto University Forest (58). Kyoto. 1986

3) APPLICON Incorporated : Applicon Color Plotting System Mapping Software User's Manual. Massachusetts. 1980

4) APPLICON Incorporated : Applicon Color Plotting System Basic Software User's Manual. Massachusetts. 1980

5) APPLICON Incorporated : Applicon Color Plotting System Extended Basic Software User's Manual. Massachusetts. 1980